Modeling Soviet Modernization: An Economy in Transition

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Abstract: This paper uses a macroeconomic model to evaluate prospects for Soviet economic growth to the year 2000. Because of the considerable uncertainty regarding the ultimate success of Gorbachev's modernization program and reform package, and because of the long time frame of the projection, a single "most likely" forecast cannot be made. Instead, three scenarios were constructed to reflect different degrees of success for Gorbachev's initiatives. The results of these simulations provide insights into what is possible and illustrate the dynamics involved when an economy administered by central planners for nearly 70 years attempts to change its method of operation. *Journal of Economic Literature*, Classification Numbers: 027, 124, 211.

INTRODUCTION

A serious challenge facing Soviet leaders today is the state of their economy. The growth formula that propelled the USSR to world power status in the postwar era—a massive infusion of labor and capital resources—no longer seems viable. Gorbachev has thus made economic revitalization a top priority. Under his leadership, the Soviet government has initiated programs to modernize production technologies and improve productivity, and more initiatives are expected. Their success in meeting this challenge will have major implications for US-Soviet relations and the balance of power in the years ahead.

A macroeconomic model of the Soviet economy was constructed to evaluate the effects of Gorbachev's modernization program on GNP growth prospects. Specifically, the model was designed to:

(1) Distinguish between the productivity of new and old capital equipment (embodied technological change).

(2) Accommodate change in labor's contribution to economic growth originating from policies intended to improve skills and increase the work effort.

(3) Account for economic disruptions that may result from the myriad changes to entrenched economic mechanisms and practices.

The purpose of this paper is to briefly describe the model used to evaluate Soviet modernization and to present projections of Soviet economic performance to the year 2000. Because of the considerable uncertainty regarding the ultimate success of Gorbachev's modernization program and reform package, and because of the long time frame of the projection, a single "most likely" forecast cannot be made. Instead, scenarios were constructed to reflect different degrees of success for Gorbachev's initiatives. The results of these simulations provide insights into what is possible and illustrate the dynamics involved when an economy administered by central planners for nearly 70 years attempts to change its method of operation.

GORBACHEV'S MODERNIZATION STRATEGY

Since becoming General Secretary in 1985, Gorbachev has gradually put forward the most comprehensive program for economic modernization since Khrushchev. While some aspects of the program have already been put into place, the bulk of Gorbachev's "new economic mechanism" will not be fully implemented until after the start of the Thirteenth Five-Year Plan in 1991.[2] At the core of the modernization program are efforts to increase the productivity of labor and capital.

Capital Modernization

Gorbachev's capital modernization initiatives include programs to increase the quality of new capital as well as the technology of production embodied in the machinery and equipment comprising the new capital. This is to be accomplished by substantially increased investment growth targeted principally at the machine-building sector—the carrier of new technology. The intent of this new strategy is to renew the Soviet capital stock by a combination of high rates of investment and an increase in the rates of retirement of old plant and equipment. Plans for 1986–1990 call for an 80% increase in investment in the eleven civilian machine building ministries compared with the 1981–1985 period. The retirement rate of productive fixed capital is slated to rise from 1.8 percent in 1985 to 3.1 percent in 1990, while the retirement rate for the machinery component of productive fixed capital is to climb from 3.2 percent to 6.2 percent.

[2] In his June 26, 1987 plenum report, Gorbachev said: "The radical reform of the system of economic management is not a single act but a process for whose completion a certain amount of time will be needed . . . we must enter the 13th five-year plan with a new economic mechanism, although its development will continue even in the following five-year plan" (*Pravda*, June 26, 1987, second edition, p. 5).

Accelerated investment growth represents the quantitative dimension of Gorbachev's program, but the qualitative dimension of the program is more important. The returns to new investment depend heavily on the technological level of the new plant and equipment being installed and the efficiency with which it is used. Specific aspects of the program to increase the level of technology include:

(1) Creation of interbranch scientific and technical complexes to expedite development and assimilation of new technologies into the machine-building production base.

(2) An increase in expenditures for "science"—a rough indicator of the resources committed to research and development—by 35 percent during the 1986–1990 period, as compared with the 1981–1985 period.

(3) The introduction of a new system of quality control, known as State Acceptance, to put teeth into Gorbachev's plan to improve product quality.

(4) An increase in the supply of more technologically advanced equipment. For example: production of robots in the 1986–1990 period is to increase by 120 percent, numerically controlled machine tools by 90 percent, and machining centers by 330 percent compared with production in 1981–1985; by 1990 the Soviets plan to produce 1.1 million personal computers per year, compared with almost none until the mid-1980s.

Results of the USSR's Central Committee Plenum in June 1987 indicate that Gorbachev intends to go beyond the tinkering that characterized the 1979 Brezhnev economic reform decree and the experiment in industry introduced under Andropov and Chernenko. Gorbachev's major achievement at the plenum was the approval of a landmark program for comprehensive economic reform that would, if fully implemented, reduce central control over economic activity and provide a broader scope for market forces. Also approved were eleven draft decrees detailing changes in major sections of the economy, and a new law on enterprises designed to expand their decisionmaking powers and force them to be financially responsible for their activities. It is not clear, however, that these reform measures will be fully implemented, and even if they are, it is not clear that they will achieve the desired results (Schroeder, 1987).

Labor Force Strategy

The success of Gorbachev's program will also depend on the performance of the Soviet work force. A combination of measures is being

implemented to strengthen discipline, improve labor utilization, enhance worker incentives, and provide more skilled labor. These measures represent the "human factors" in Gorbachev's program.

The campaign for labor discipline, which was initiated by Andropov and foundered somewhat under Chernenko, has been revived in a new form. Workers at all levels are being told they could lose their jobs if they don't perform. The anti-alcohol campaign scored initial success, cutting alcohol consumption sharply and thereby reducing drunkenness and absenteeism. These campaigns are credited by the Soviets with contributing to the improvement in labor productivity in 1986.[3]

Moscow has long tried to improve labor utilization. Gorbachev has intensified this effort through a number of initiatives including:

(1) *Work position certification.* Under this program, begun in 1985, all enterprises are charged with making a systematic inventory and evaluation of their labor and equipment—with the aim of eliminating low productivity jobs and obsolete machinery.

(2) *Mechanization.* Moscow hopes that the mechanization of labor intensive processes can free 20 million workers from manual labor by the year 2000. Five million manual workers are to be released during the 1986–1990 plan period, as compared to a reported reduction of less than half that figure in 1981–1985.

(3) *Wage Reform.* The implementation of a new wage system in Soviet industry began on January 1, 1987. The new system is designed to improve incentives to perform well and acquire advanced skills by reversing the long-standing trend towards wage-levelling. Under the new system, sharply higher wage increases would go to those with skills vital to the modernization program—engineers, designers and skilled labor in machine building. Wage increases are to be funded by the enterprises themselves through increases in productivity and savings in the wage fund created by releasing excess labor.

Moscow has also initiated reforms in education that are intended to increase the quality of new labor. A program was adopted in March 1987 to overhaul the Soviet specialist training system, in an effort to make it more responsive to the needs engendered by technological change and industrial modernization. The program calls for fewer but better trained graduates in engineering, in part through closer cooperation between industry and higher education. It includes tougher admissions standards,

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[3]In his June 26, 1987 plenum report, however, Gorbachev admitted that the campaigns are now flagging, saying "in many places the momentum has been lost . . . The incidence of drunkenness has increased again and idlers, parasites, and pilferers . . . again feel at liberty" (*Pravda*, June 26, second edition, p. 2).

a more rigorous system of evaluating student performance and special training for the best students. New curricula, texts, and teaching methods are to be developed by 1989. Schools are to cut down on the number of specialties and provide a general scientific background, emphasizing independent study rather than rote learning, and practical training in enterprise-sponsored facilities.

THE MODEL

The primary purpose of the model is to explore the impact of Gorbachev's modernization program on the *real* growth of Soviet GNP.[4] The model uses a supply-side approach in which projections of capital and labor are used to solve production functions for each of twelve sectors, which are then totaled to obtain GNP.[5]

Production Functions

At the heart of the model are production functions linking net outputs capital and labor inputs in twelve sectors of the economy. The production functions were constructed by modifying the basic Cobb-Douglas functional form to allow for technological progress embodied in the capital stock. This requires distinguishing between output produced using "old" capital from output produced using new capital, which potentially includes technologically advanced and higher quality machinery and equipment. For this purpose, the capital stock was separated into three "vintages": pre-1986 capital ("old" capital), 1986–1990 capital, and 1991–2000 capital.

Technological progress is incorporated into the model in two ways, depending on the sector of the economy. In the first method, the capital elasticity (percentage change in output for a 1 percent change in the capital input, holding other factors constant) for new capital is set higher than that for old capital, thus making new capital more productive.[6] This

principal conceptual difference between GNP and Soviet reported national income is the latter's inclusion of (1) most personal services as well as services provided by the government (for example, health, education, housing, personal transportation and communications, recreation and personal care, government administration, credit and insurance, research and development, and military personnel) and (2) depreciation on fixed capital. For a discussion of the methodology for constructing national economic accounts for the Soviet Union along Western lines see JEC, 1982.

twelve sectors include transportation and communications, construction, services (less housing), housing, agriculture, domestic trade and other, and six industrial branches—machine building, chemicals (including ferrous metals, nonferrous metals, forest products, construction materials, and industrial fuels, electric power, consumer goods (including light industry and food processing) and industrial branches of industry). A minor contribution to GNP by military personnel is also included.

Increasing the capital elasticity implies more than just an increase in the quality of capital—it implies a fundamental change in the nature of the capital (such as automation), as well. The improved production technology embodied in the new capital in turn implies a reduction in the contribution of labor relative to that of capital in the production process (that is, capital "substitutes" for labor). This approach seemed to be in keeping with the spirit of "restructuring" proposed by Gorbachev.

method was used for all sectors except agriculture, services, housing, and the electric power branch of industry. The second method is to multiply the new capital input by a "capital productivity factor" to simulate an increase in quality without an accompanying change in the technology of production. This method was used for agriculture, services, and electric power, where increases in the quality of capital might occur—resulting in greater output per unit of new capital—but where new, improved technologies are not expected.[7]

In both methods, the productivity of old capital is constrained to that observed in the recent past. That is, the capital elasticity parameter for old capital, β, was estimated using historical data and thus reflects actual returns to capital during the recent past (Table 1). The labor requirement for capital stock of vintage prior to 1986 is set equal to the labor actually used in 1985, thereby providing old capital with the same labor resources it has received in the past. The remaining labor resources are made available to new capital.

The production function for agriculture differs from production functions for other sectors in two ways; weather is included in the function, and the labor input is not disaggregated and allocated according to the capital vintage. Weather effects are modeled by expanding the intercept term—$\alpha(t)$—to include relevant weather variables. Labor was not disaggregated as done for other sectors because labor in agriculture is much more fungible than in other sectors, making it impractical to allocate a portion of the agricultural labor force exclusively to new capital. Gains in productivity from higher quality farm machinery and equipment were incorporated into the capital productivity factor.[8]

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[7]Generalized equations for the two forms of the production functions are:

$$Q = \alpha(t) [K_0{}^\beta (HF^*L_0)^{1-\beta} + Kn_1{}^\gamma (HF^*Ln_1)^{1-\gamma} + Kn_2{}^\delta (HF^*Ln_2)^{1-\delta}], \text{ and}$$

$$Q = \alpha(t) [K_0{}^\beta(HF^*L_0)^{1-\beta} + (KPF_1{}^*Kn_1)^\beta(HF^*Ln_1)^{1-\beta} + (KPF_2{}^*Kn_2)^\beta (HF^*Ln_2)^{1-\beta}],$$

where

Q = value-added output (constant prices),
K_0 = capital stock of vintage prior to 1986 ("old" capital),
Kn_1 = capital stock of 1986–1990 vintage,
Kn_2 = capital stock of 1991–2000 vintage,
L_0 = labor input *required* by "old" capital,
Ln_1 = labor *required* for the 1986–1990 vintage capital,
Ln_2 = labor *available* for the 1991–2000 vintage capital,
$\alpha(t)$ = intercept term and adjustment cost factor,
β = capital elasticity for "old" capital,
γ = capital elasticity for 1986–1990 vintage capital,
δ = capital elasticity for 1991–2000 vintage capital,
HF = "human factor" multiplier,
KPF_1 = capital productivity factor for 1986–1990 vintage capital, and
KPF_2 = capital productivity factor for 1991–2000 vintage capital.

[8]The resulting production function for agriculture is:

$$Q = \alpha_1(W) \alpha(t) (K_0 + KPF_1{}^*Kn_1 + KPF_2{}^*Kn_2)^\beta (HF^*L)^{1-\beta},$$

where $\alpha_1(W)$ is the adjustment function for weather.

Table 1. Production Function Parameters[a]

Sector	α	Capital elasticity (β)	Slump parameter (α_1)
Industrial materials	.297613	.454937	-.026580
MBMW	.128875	.523432	-.027334
Chemicals	-.384510	.727752	-.050993
Consumer goods	.297141	.422763	-.0075427
Fuels	2.156876	.039291	—
Electric power	-1.104020	.891543	-.015004
Construction	.716375	.285576	-.022500
Transportation and communications	.502982	.329566	—
Domestic trade, other	.683270	.175383	—
Services	.334064	.197748	—
Housing	.688387	.478880	—
Net agriculture	—	.162360	-.057260

Parameters were estimated stochastically by fitting a modified Cobb-Douglas production function h data on capital, labor, and output for 1969-1985. The general form of the production function was:

$$Q = \alpha(t)\, K^{\beta}\, L^{1-\beta},$$

:re

Q = output measured in 1982 rubles at factor cost,
K = average capital stock in 1973 rubles,
L = average employment in man-hours,
t) = scale adjustment and adjustment for 1976-1982 industrial growth slowdown period, and
β = capital elasticity.

nployment data were obtained from Heleniak and Rapawy (1987); capital data were obtained from *hoz* (various issues); and output data were obtained from the Central Intelligence Agency (see :zweg, 1987). The function $\alpha(t) = e^{\alpha + \alpha_1 \cdot SLUMP}$, where SLUMP defines the intensity and duration of :conomic stagnation. The function $\alpha(t)$ was estimated for the seven sectors that exhibited a growth "down" during the 1976-1982 period—industrial materials, machine building, chemicals, consumer s, electric power, construction, and agriculture. The remaining sectors—transportation and com-ications, domestic trade and other, housing, fuels, and services—did not exhibit any shifts in the uction function during this time, and so estimates of a constant intercept were made.

he model also allows for productivity gains originating from "human ors" by multiplying labor by a "human factor" multiplier, HF. Human or effects were modeled for labor allocated to both old and new tal. Human factor effects modeled by HF are those that result from regime's efforts to institute better management and planning, the ipline and antialcoholism campaigns, and improved labor incen-s—policies that act to increase the productive utility of labor (that is,

factors that make the real labor effort more intensive while the nominal measure of labor remains unchanged). For example, setting HF = 1.10 implies that the efficiency of labor will be 10 percent greater than the average observed during the recent past.

Changes in the production technologies of an economy cannot be accomplished without adjustment costs, and the faster the pace of the transformation, the greater they will be.[9] A variable called "SLUMP" was introduced into the production functions to explore the effects of these adjustment costs during the transition period.

To project output for each sector using these production functions, it is necessary to first project the labor each sector will have at its disposal in the future, and planners' allocation of new capital resulting from invest-ments during 1986 and beyond.

Forecasting Labor

Forecasts of labor inputs for the model were based on a projection of the Soviet labor force to the year 2000 made by the US Bureau of the Census, Center for International Research (Heleniak and Rapawy, 1987). Estimates of total hours worked are allocated to the twelve sectors on the basis of their respective shares in total capital investment. Pre-1986 vintage capital (old capital) is allocated the amount of labor actually used; remaining labor in each sector (total labor allocated to the sector less labor for pre-1986 vintage capital) is "new labor" available for 1986 and newer capital (new capital).[10]

[9]To model these expected adjustment costs, the intercept term in the original Cobb-Douglas specifica-tions was expanded to a function of time—$\alpha(t)$—to permit downward shifts in the production function during the transition period, as follows:

$$\alpha(t) = e^{(\alpha_0 - \alpha_1 SLUMP)},$$

where SLUMP is a variable that simulates the intensity of the adjustment costs, α_0 is a scaling parameter, and α_1 is the adjustment cost parameter for each sector.

[10] $$L = L_{-1} + \lambda_1 \lambda_2 \Delta M,$$

where

L = labor in man-hours allocated to a particular sector,
ΔM = the increment of new workers entering the civilian economy,
λ_1 = parameter converting number of workers to man-hours, and
λ_2 = share of new workers allocated to a particular sector as a function of the capital investment share and the historical relationship between investment allocations and the employment increment.

Within each sector, labor required by "old" capital (L_0) is set by multiplying the amount of "old" capital by the inverse of the capital-labor ratio in 1985. Additional labor from increases in the overall labor supply (ΔM) and from labor displaced by retirement of old capital is allocated to new capital. Equations for L_n and L_0 are

$$L_0 = \omega K_0 \text{ and}$$
$$L_n = L - L_0,$$

where ω is the inverse of the 1985 capital-labor ratio.

Forecasting Capital

Values for new capital are generated by accumulating commissionings of new plant and equipment beginning in 1986.[11] Old capital is the total capital stock at the end of 1986 minus retirements. Thus, new capital in each sector projected in 1986 is the additions to the capital stock estimated in that sector for that year. In 1987, new capital is the 1986 additions plus additions to new capital in 1987. Old capital at the end of 1987 is total capital stock at the end of 1986 less retirements of capital stock in 1987.[12] Retirements are calculated by multiplying the total capital stock at the beginning of the year by the planned retirement rate. Commissionings are generated from new fixed investment, which in turn is generated by output from the machine building and construction sectors.[13] Total new fixed investment is distributed among sectors of the economy exogenously, typically according to published Soviet plans.

SIMULATING ECONOMIC PERFORMANCE TO THE YEAR 2000

The model was used to evaluate economic prospects of Gorbachev's revitalization program for 1986–2000. There is considerable uncertainty in projecting Soviet economic growth that far into the future. First, the extent to which Gorbachev's programs will be implemented is unknown; and if implemented, the achievement of measurable advances in technological progress is uncertain. In addition, uncertainty about future values of "exogeneous" variables—such as the price of oil and volume of trade with the West—grows large as the projection period extends beyond about five years. Furthermore, there is little information about Soviet plans in the 1990s (such as plans for investment growth, investment location, and capital retirement rates).

Commissionings are gross additions to capital, including: the value of new enterprises, buildings, and installations completed and put in service; the value of all types of equipment put into service; the value additional production tools; the value of additions to perennial plantings; the cost of work to irrigate and drain land; and other outlays augmenting the value of fixed assets.

The equations are

$$K_n = K_{n-1} + C,$$
$$K_0 = K_{0-1} - R,$$

where K = value of capital stock at the end of the year,
R = retirements of capital stock, and
C = commissionings.

Commissionings are generated as a weighted average of new fixed investment for the current year and up to three previous years. Total new fixed investment is calculated by adding machinery imports to output from the machine building and construction sectors, and subtracting the amount of machinery, equipment, buildings, and structures allocated for export, capital repair, consumer durables, and military procurement. Capital repair is estimated using an equation that relates previous capital repair costs to the size of the capital stock. Other end-uses for machinery, equipment, buildings and structures set exogenously.

Although sufficient information is not available to make a precise projection, alternative scenarios can be *simulated* to provide insights about what is possible. Three scenarios are developed. The first scenario assumes the trends of the recent past extend into the future without change, in effect assuming Gorbachev's program has no effect either positive or negative. The last two scenarios project growth under the assumption that Gorbachev's program is vigorously implemented during the next 4–5 years, causing changes in long-standing "economic mechanisms" and practices that prove disruptive in the short run.[14] The difference between these latter two scenarios is determined by whether Gorbachev's program succeeds or fails. If his initiatives ultimately take hold, growth would likely accelerate in the 1990s. Production would not only be at a higher level, but would also be *qualitatively superior*. If, on the other hand, his initiatives are thwarted and fail to generate more and better output after the initial period of disruption, then the growth slump would continue and the quality and mix of output would change very little.

Assumptions underlying the three scenarios differ only with respect to the success of Gorbachev's modernization program and assumptions about its impact on machinery imports, production of consumer durables, and weapons procurement costs. These differences are summarized in Table 2.

Investment shares were derived from an estimated structure of Soviet capital investment for 1986–1990 (Leggett, 1987). These rates were extended to the 1991–2000 period under the assumption that the modernization drive would continue to be the top priority throughout the 1990s. Retirement rates for 1986–1990 were increased above the 1985 retirement rates at constant annual increments such that the 1990 rates were 75 percent of the planned retirement rate for 1990.[15] Retirement rates for 1991–2000 were held constant at the 1990 level. Values for other parameters and exogenous variables were set to reflect recent trends (1981–1985 in most cases). All scenarios incorporate actual economic performance for 1986.

The most important (and most uncertain) aspect of simulating the future of the Soviet economy is projecting the returns to new capital and human factors. The extent to which the modernization parameters—γ, δ, HF, KPF_1, and KPF_2—will increase as a result of Gorbachev's initiatives cannot be estimated statistically. Instead, informed judgments were

[14]In his June 26, 1987 plenum speech, Gorbachev acknowledged there had already been some disruption resulting from "restructuring," when he said: ". . . in the first months of the year grave errors were committed which led to disruptions in many areas of the economy. Both the Politburo and the government had to take urgent measures to rectify the situation. Even though the situation is returning to normal, considerable damage has nevertheless been done" (*Pravda*, June 26, 1987, second edition, p. 1).

[15]The planned retirement rate for all productive capital is 3.1 percent by 1990, which is a 47 percent increase over the 2.1 percent rate for 1985. If only 75 percent of the planned goal is achieved, as assumed here, the overall retirement rate will increase 36 percent by 1990.

...during the Three Scenarios

Assumptions	Gorbachev "doesn't matter" 1986–2000	Gorbachev "wins" 1986–1990	Gorbachev "wins" 1991–2000	Gorbachev "loses" 1986–1990	Gorbachev "loses" 1991–2000
Trade and End-use Assumptions (annual growth rates in percent)					
Machinery imports	0	1	3	1	1
Machinery exports	3	3	3	3	3
Consumer durables	4	3	5	3	3
Weapons procurement	1	1	1	1	2
Modernization Assumptions[a]					
Capital elasticity assumptions[b] (percent increase above pre-1986 trends)					
All but machine building	0	3	15	3	3
Machine building	0	5	25	5	5
Capital productivity factor assumptions[c] (percent increase above pre-1986 trends)	0	2	10	2	2
HF assumptions (percent increase above pre-1986 trends)	0	1	4	1	1

[a]In addition to these assumptions, differing assumptions were made regarding adjustment costs. In the "Gorbachev doesn't matter" scenario, no adjustment costs were postulated since the modernization program is completely discounted in this scenario. The intensity of the short-run growth slump is determined in the model by the variable "SLUMP." For the scenario "Gorbachev wins," SLUMP was set equal to 0.5 in 1987, 1 in 1988, 2 in 1989, 1 again in 1992 (simulating a partial recovery), and 0 after 1992 (simulating a complete recovery). The same weights were used for the "Gorbachev loses" scenario through 1991, but weights remained at the 1991 level through the year 2000, precluding any recovery.
[b]Applies to all sectors except agriculture, services, and electric power.
[c]Applies to services, electric power, and agriculture.

made about the most likely outcome under the assumption that the program is vigorously implemented.[16]

Scenario 1:
Gorbachev "Doesn't Matter"

In this scenario, no allowance is made for modernization. Energy, raw materials, and transportation constraints become no worse, and trends in labor productivity, the return to capital, exports, imports, and other factors are assumed to continue as they had in the 1981–1985 period.[17] It is as if Gorbachev's reform program "doesn't matter" (that is, political change begets no real economic change). Because no serious attempt is made to implement Gorbachev's reform measures in this scenario, adjustment costs are disregarded.

Under these conditions, the average annual growth rate for total GNP would be 2.3 percent in 1986–1990, and would then drop to 1.5 percent in the 1990s (Table 3), assuming "average" weather. When the uncertainty of weather is factored into the analysis, the most likely *range* for average growth per year is 1.8–2.7 percent for 1986–1990 and 1.3–1.7 percent for the 1990s.[18] More importantly, the means of production would remain pretty much the same, and the same mix of goods would be produced with little improvement in quality or advancement in technology. The 2.3 percent growth rate for 1986–1990 is higher than projected in the following scenarios, where Gorbachev's reforms and initiatives are seriously implemented, but the composition and quality of the goods produced would be inferior.

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[16]The macroeconomic model outlined above was used to determine the gains from capital modernization and from human factor effects required to meet the implied non-agricultural GNP growth goal in the Twelfth Five-Year Plan—4.1 percent per year. In terms of labor productivity, the annual labor productivity growth rate would have to be 3.3 percent to meet the GNP growth goal, which is three times greater than the 1981–1985 average of 1.1 percent per year. The Soviets' plan states that new machinery and technology will account for more than two-thirds of this increase in productivity. This goal is attainable if HF increases 9.8 percent and γ or KPF increases 11.0 percent. Returns in these ranges by 1990 are highly unlikely because the bulk of Gorbachev's initiatives have yet to be implemented, and because there are natural impediments to rapid technological advancement in the Soviet economic system (such as the lack of incentives to innovate, the lack of quick access to quality information, and the inflexibility of the production process).

[17]In terms of the model, γ and δ were set equal to β, and HF (human factor multiplier), KPF_1 and KPF_2 (capital productivity factors) were set equal to one, and the function $\alpha(t)$ was estimated with the variable "SLUMP" equal to zero, thus precluding the possibility of production losses owing to economic disruption.

[18]The uncertainty of weather was incorporated into the analysis with stochastic simulation (also called Monte Carlo analysis). Agricultural output was predicted for each year by randomly choosing values for the weather variables according to probability distributions estimated on the basis of an 18-year data set (1969–1986). A "most likely" range estimate was derived from the probability distribution of the estimated output. The most likely range is defined to exclude outcomes in each tail of the output distribution with less than a 10 percent chance of occurring. That is, we can conclude that there is about a 10 percent chance that weather will be *so unfavorable* as to result in growth below the lower limit of the range, and about a 10 percent chance weather will be *so favorable* that growth will exceed the upper limit of the range.

3. Simulation of Soviet Economic Performance to the Year 2000

Scenario	Average annual growth rates[a] (percent)		
	1986–1990	1991–2000	1986–2000
Total GNP[b]			
pachev "doesn't matter"	2.3 (1.8–2.7)	1.5 (1.3–1.7)	1.8 (1.6–1.9)
pachev "wins"	1.9 (1.4–2.3)	2.9 (2.7–3.1)	2.6 (2.4–2.7)
pachev "loses"	1.9 (1.4–2.3)	1.6 (1.4–1.8)	1.7 (1.6–1.8)
Industry			
pachev "doesn't matter"	2.9	2.7	2.8
pachev "wins"	2.3	5.5	4.4
pachev "loses"	2.3	2.9	2.7

vth rates for 1986–1990 use 1985 as a base, and growth rates for 1991–2000 use the estimated
r *1990* as a base. Actual results for 1986 are factored into the analysis.
point estimate (upper figure) assumes "average weather." A most likely range, given in paren-
vas derived by incorporating the uncertainties of weather into the analysis. The most likely
eans there is a 10 percent chance growth could be below the lower limit of the range and a 10
chance it could exceed the upper limit of the range. The base used to calculate the growth rate
r 1991–2000 was the estimated *median* value for 1990.

ario 2: Gorbachev "Wins"

s scenario is based on the judgment that, while gains from human
s are possible without sacrificing output, significant technological
ess can be obtained *only* by making changes to the Soviet system
vould result in considerable disruption for a few years while the
n adjusts. During the adjustment period, growth would slow in
nge for the increased ability to produce more and better output in
'90s. It is as if Gorbachev "wins," but has to pay the price.[19]
1986–1990 as a whole, an increase in the capital elasticity (γ) for *new*
l in machine building (where the modernization drive is most
y focused) of about 5 percent is probably possible if the State
tance program and other restructuring initiatives are fully and
tently implemented. This is an *average* increase that applies to the

ent, there are no indications that Gorbachev's program will not be vigorously implemented. In a
elivered to a conference of the party Central Committee in July, 1987, Gorbachev criticized the
hine-building industry for insufficient progress in raising the technological level of machinery,
; that "no retreat is possible" and demanding that Soviet machinery achieve the highest "world
s" in less than seven years.

entire stock of new capital, of which genuinely new products would
represent only a small proportion. In addition, it is an average for the
entire five-year period. Because the intensity of the reform program is
less in other sectors, the increase in the capital elasticity was set at 3
percent and the increase in the capital productivity factor (KPF) was set at
2 percent for remaining sectors. Similarly, gains from programs directed
towards "human factors" is assumed to increase HF (the productive
utility of labor) by an average of about 1 percent for all sectors. Higher
gains from human factors would probably not occur before 1990 because
of the disruption created by the reforms and the expected low growth of
consumer goods.

To simulate the economic disruption resulting from these changes, a
"slump" period was created in the model for 1987–1992 that was roughly
equivalent to two consecutive years during the 1976–1982 growth slow-
down period, followed by a complete recovery after 1992. Sectors
affected were industry, construction and agriculture; other sectors were
assumed to be unaffected by the disruptions, following from historical
precedent.

In exchange for this "sacrifice" during 1987–1992, increases in the
capital elasticities for the 1990s were quintupled (see Table 2). In addi-
tion, HF was increased an additional three percentage points to 4 percent
under the assumption that the gains in modernization would stimulate a
sharp increase in worker effort in response to increased availability of
better consumer goods, housing, and an "up-beat" atmosphere in the
workplace. Some improvement in the quality of the workforce is
expected in the 1990s, as well.

As a result of the economic disruptions during the adjustment period,
economic growth for 1986–1990 would be below the rates of recent
years, but in return, growth would increase in the 1990s to rates enjoyed
by the Soviets in the early 1970s (Figs. 1 and 2). Assuming "average
weather," average annual GNP growth for 1986–1990 would be 1.9
percent, and which would then increase by one percentage point to 2.9
percent in the 1990s (Table 3). GNP growth slightly above 3 percent per
year is even possible in the 1990s if favorable weather prevails. In indus-
try alone, growth in the nineties would be more than double that for
1986–1990 (Fig. 3).[20] More important, the goods produced during the
1990s would be of higher quality, greater diversity, and meet consumer
and producer demand more closely.

Scenario 3: Gorbachev "Loses"

The third scenario replicates the previous scenario through the
1986–1990 period, but postulates that Gorbachev's programs, while

[20]Average investment growth for 1986–1990 in this scenario roughly corresponds to the Soviets' target
of 5 percent per year, which is about twice as high as would be obtained under the assumptions of the
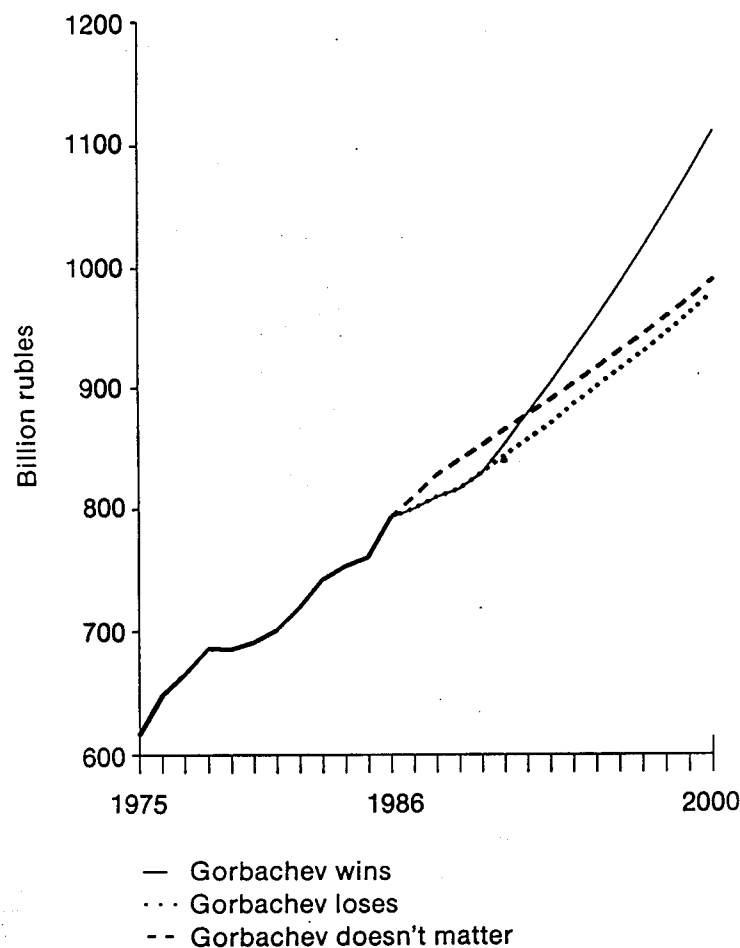"Gorbachev doesn't matter" scenario.

Fig. 1. Projections of Soviet GNP.

In this scenario, the average annual growth rate for GNP for 1986–1990 would be the same as in the previous scenario, 1.9 percent (assuming average weather). This would be followed by an average annual growth rate of 1.6 percent in the 1990s, approximately equivalent to performance under the assumptions of the "Gorbachev doesn't matter" scenario. The means of production would change slightly for the better, and the product mix and quality of goods would increase some, but overall, Gorbachev's attempts to modernize the Soviet economy would fail. This failure would be reflected in the continuation of low growth throughout the 1990s. By the year 2000, the difference between "winning" and "losing" amounts to 133 billion rubles per year, equivalent to total investment in the economy in 1976.
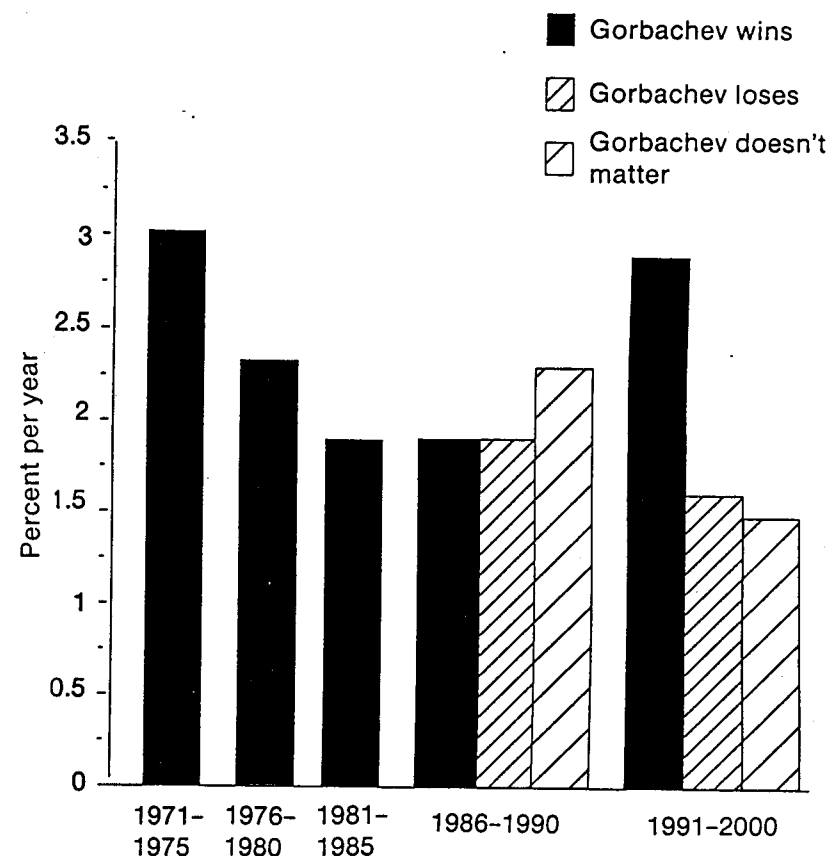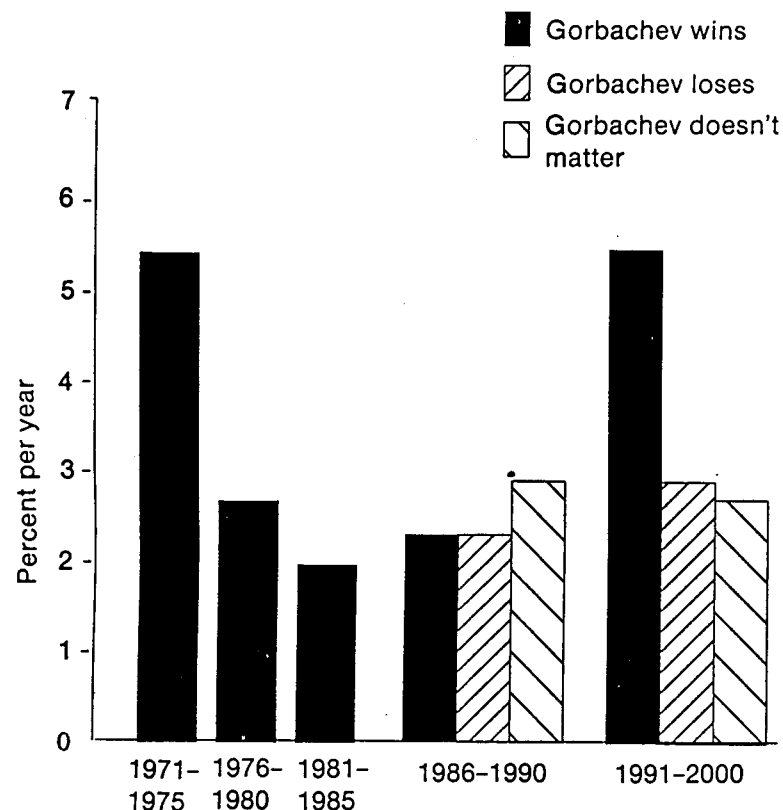
Fig. 2. Average annual growth for Soviet GNP.

implemented, fail to raise technology to a more efficient level. Economic disruptions occur, but there is no recovery from the 1987–1990 slump, and consequently no payoff of higher productivity in the 1990s. It is as if Gorbachev tries, but "loses." This situation could arise if new programs further distort economic mechanisms, moving production technologies to a less efficient level (more red tape, instead of less, for example). Political turmoil and frequent changes in objectives could contribute to the permanent slump. Some gains in human factors and return to capital are postulated (equal to those in the 1986–1990 period in the previous scenario), but no additional gains occur in the 1990s.

Gorbachev wins

Gorbachev loses

Gorbachev doesn't matter

Fig. 3. Average annual growth for Soviet industry.

IMPACT OF ADJUSTMENT COSTS ON SOVIET GNP GROWTH

The extent and duration of the temporary disruption period depends on how fast the changes are made and how disruptive the changes will be. For the "Gorbachev wins" and "Gorbachev loses" scenarios, the assumed level of adjustment costs was about 150 billion rubles (1982 prices) when totaled over 1986-2000.[21] However, other patterns of adjustment costs are possible.

Two additional scenarios were created that repeated all assumptions in the "Gorbachev wins" scenario, except that the pattern of adjustment costs was allowed to vary while holding the total costs equal to 150 billion rubles. A shorter but deeper adjustment cost pathway resulted in

[21]This was determined by comparing total GNP for 1986-2000 for the "Gorbachev wins" scenario to an identical scenario with all adjustment costs excluded (that is, SLUMP = 0 for the entire projection period).

a 1.6 percent annual GNP growth rate for 1986-1990, whereas a longer but shallower pathway resulted in 2.3 percent growth (compared with 1.9 percent growth for the original "Gorbachev wins" scenario). By assumption, gains from modernization are the same as in the original "Gorbachev wins" scenario for both of these scenarios. The difference between 1.6 and 2.3 percent growth is perhaps large enough to have political significance, and suggests that Gorbachev could minimize the political cost by stretching out the adjustment period (Table 4). Indeed, comparison of his rhetoric and actions suggests he may be doing just that—calling for revolutionary changes (by Soviet standards) but compromising on their implementation.

It is also possible that even greater adjustment costs will be necessary in order to achieve the modernization gains simulated in the "Gorbachev wins" scenario. Additional simulations showed that doubling and quadrupling the total adjustment costs by deepening the adjustment cost pathway and (for the latter scenario) extending it through 1995 resulted in only a marginal reduction in the average annual growth rate for the 15-year projection period (Table 4). Although growth in the 1986-1990 period was quite low for these two scenarios, gains from modernization in the 1990s more than offset the additional adjustment costs. When compared with the original "Gorbachev wins" scenario, GNP in the year 2000 was only 12 billion rubles lower when total adjustment costs were

Table 4. Impact of Adjustment Costs

Adjustment costs	Average annual growth rates[a] (percent)		
	1986-1990	1991-2000	1986-2000
Total adjustment costs = base level (150 billion rubles)			
Original "Gorbachev wins" scenario (scenario A)	1.9	2.9	2.6
Shorter but deeper adjustment cost path	1.6	3.0	2.6
Longer but shallower adjustment cost path	2.3	2.7	2.6
Total adjustment costs = 2 X base level (scenario B)	1.4	3.0	2.5
Total adjustment costs = 4 X base level (scenario C)	1.0	3.0	2.4

[a]Growth rates for 1986-1990 use 1985 as a base, and growth rates for 1991-2000 use the estimated value for 1990 as a base. Actual results for 1986 are factored into the analysis.

doubled, and 32 billion rubles lower when total adjustment costs were quadrupled. GNP in the year 2000 was still much higher for these two high-cost scenarios than would be obtained under the "Gorbachev doesn't matter" scenario (Fig. 4).

The conclusion that can be drawn from these additional simulations is that improved growth in the 1990s is expected regardless of the extent or duration of the adjustment period, under the strong assumption that Gorbachev's modernization drive is vigorously implemented and substantial modernization occurs.
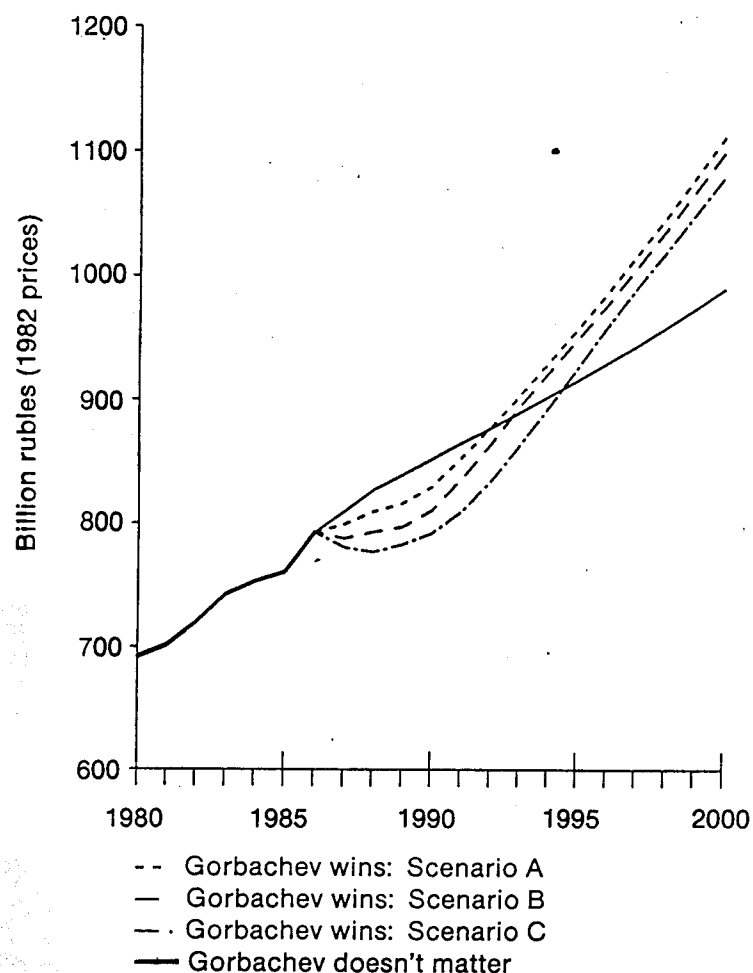

- - Gorbachev wins: Scenario A
— Gorbachev wins: Scenario B
— · Gorbachev wins: Scenario C
■— Gorbachev doesn't matter

Fig. 4. Effect of adjustment costs on Soviet GNP.

CONCLUSIONS

Gorbachev's program to modernize the Soviet economy is intended to achieve sharp changes in long-standing relationships between inputs (capital and labor) and output that will alter the growth path of the economy during the rest of this century. His modernization and reform program represents the most intense and comprehensive effort to deal with Soviet economic problems in decades. Its aggressive implementation, in fact, is causing serious disruptions and turbulence in the economy and is expected to cause more as the various bureaucratic factions attempt to adjust to the many changes being imposed from above:

- Gorbachev's quality control program is disrupting production and the supply network as poor quality goods are rejected.

- New initiatives in organization and management are creating confusion and apprehension in some quarters, and bureaucratic foot-dragging and outright resistance in others.

- The rapid pace of Gorbachev's reform program imposes a staggering set of tasks on the central bureaucracies and on the producing units, while simultaneously demanding fulfillment of the 1986–1990 plans.

- The sharp reallocation of limited investment resources will undoubtedly lead to imbalances in production and new capacity.

The results of simulations using this model indicate that the Soviet growth goals of 4 to 5 percent per year—measured in real terms—are well beyond reach. Nevertheless, under the right circumstances, economic performance may be good enough for Gorbachev to declare his program a success. If Gorbachev's program continues to be vigorously implemented (as appears at present to be the case), the cost of adjusting to the new conditions will be a period of disruption that could depress economic growth over the next few years considerably below 2 percent per year. But if Gorbachev's policies begin to take hold, bringing higher returns to new capital equipment and an increase in the effectiveness and productivity of the labor force, growth in the 1990s could accelerate to rates yielding an average for the decade of about 3 percent per year. More important, the mix of output would consist of both higher quality and higher technology products.

On the other hand, the period of economic disruption and slow growth could continue indefinitely if, for example, the system fails to adjust to the demands of Gorbachev's initiatives, resulting in virtually no chance of growth acceleration in the 1990s, and the mix and quality of goods produced would remain obsolete by Western standards and Soviet expectations.

It is not clear that the regime will have the will or ability to sustain the modernization drive when faced with inevitable near-term reductions in growth that will result from Gorbachev's efforts to change the way the economy operates. A likely outcome would be a more prolonged time-frame for restructuring, which would in turn delay the gains from modernization.

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